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Complete Rations for Dairy Cattle and Their Effect Upon Digestibility, Rumen Volatile Fatty Acids and Milk Fatty Acids.

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COMPLETE RATIONS FOR DAIRY CATTLE AND THEIR EFFECT UPON DIGESTIBILITY, RUMEN VOLATILE FATTY ACIDS AND MILK FATTY ACIDS

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ABSTRACT

Feeding trials were conducted with lactating and non-lactating dairy cows to investigate the effect of ad libitum feeding of three complete rations and a conventional ration (concentrate and roughage fed separately) on the rumen volatile fatty acids, milk fatty acids and digestibility of the rations. Some economic aspects were also considered.

The complete rations fed were 30% roughage and 70% concentrate, with the roughages consisting of alfalfa hay (II), cottonseed hulls (III), or native grass hay (IV). Alfalfa hay was used as the roughage (30%) source in the control ration (I) and a mixture of ground yellow corn, soybean meal, cottonseed meal, urea, molasses, vitamins and minerals was used as the concentrate portion of the experimental rations.

Sixteen high producing Holstein cows (26.6-32.8 kg milk/day) were blocked according to their level of production, stage of lactation and estimated real producing ability, and randomly assigned to the experimental rations. The experimental design was a continuous trial (120 days) randomized block design with a split-plot in time (period of 10 days). Digestibility trials were conducted using the chromic oxide indicator method, milk fatty acids were analyzed, TDN requirements for production and returns above feed cost were calculated.

Four rumen-fistulated non-lactating dairy cows were randomly assigned to the experimental rations and the excretion patterns of chromic oxide, effects of rations on the rumen volatile fatty acids as a function of time (0, 2, 4, and 6 hr after feeding) and the digestibility of the rations by the total collection method were determined.

Trials with lactating animals revealed digestible energy and TDN coefficients of (I) 71.5%, 57.4%; (II) 70.9%, 55.9%; (III) 64.5%, 53.6%; and (IV) 62.2%, 52.5%, respectively. Therms of digestible energy intake and kg TDN intake were found to be, (I) 67.6, 12.8; (II) 69.9, 13.3; (III) 68.5, 14.0; and (IV) 59.2, 12.3, respectively. No uniform trends could be observed in the levels of fatty acids in the milk fat. The average kg TDN/kg 4% FCM for the rations were, (I) 0.41, (II) 0.38, (III) 0.51, and (IV) 0.44. Trials with lactating cows revealed that when ad libitum feeding of complete feeds was practiced, the most efficient producers were at the higher levels of production. Daily feed cost and daily returns above feed cost ($) were found to be, (I) 1.78, 1.41; (II) 1.47, 1.83; (III) 1.73, 1.22; and (IV) 1.36, 1.11, respectively.

The excretion patterns of chromium ion by the rumen-fistulated cows showed considerable variation. Average recovery rate of chromium ion when grab samples were taken at 0900 and 1900 was 94.4%, 102.2%, 98.9% and 99.7% for the control, alfalfa, cottonseed hulls and native grass hay rations, respectively, with an average recovery rate of 98.8% for all rations. Digestible energy and TDN coefficients were found to be, (I) 72.4%, 60.7%; (II) 71.3%, 59.9%; (III) 65.5%, 56.5%; and (IV) 67.2%, 55.1%, respectively. Trials with rumen-fistulated cows also indicated that rations had an effect on the levels of rumen acetate ($P<0.01$), propionate ($P<0.05$), and butyrate ($P<0.01$), and influenced the level of rumen acetate ($P<0.01$) as a function of time after feeding. Rumen acetate levels decreased 2 hr after feeding for all rations and continued to do so for the control and cottonseed hulls rations, while the acetate level increased for the alfalfa and native grass hay rations.

INTRODUCTION

The basic tool of the dairy industry is the cow and her ability to produce milk economically when properly fed. Nature's most nearly perfect food, milk, and its ability to remain so, will depend upon people engaged in the dairy industry and their ability to use the basic tools at their disposal.

Improved breeding, selection, feeding, and management practices have resulted in the development of a dairy animal which has inherited the potential to produce at high levels of production. Along with the development of this inherent ability to produce milk there has been a reduction in the number of farms with an increase in herd size, increased storage and labor cost, and mechanization of the dairy farm. These developments have forced the dairy farmer to seek new approaches in feeding dairy cattle.

Renewed interest has been developing in the use of complete dairy rations for dairy cows. These complete rations contain both roughage and concentrate components and are the only source of nutrients other than water and free-choice minerals. This approach is an attempt to correct some of the problems listed above and to provide the dairy cow with a concentrated source of energy which she can consume in adequate amounts to produce at high levels and still maintain milk fat per cent.

As in any new area of interest, little is known and research is needed to determine the value both economically and nutritionally of a complete ration fed to lactating dairy cows.

This study was undertaken in an attempt to determine the value of complete rations as compared with a conventionally fed ration and their effects on the rumen volatile fatty acids and milk fatty acids. Also, the economic aspects of complete rations were evaluated.

REVIEW OF LITERATURE

Research and sound management practices have indicated that in order to realize the genetic potential of dairy animals and produce milk economically, high levels of concentrate need to be fed. Where increased levels of concentrate have been used, various problems have been encountered, such as digestibility, production requirements, milk fat depression and economics of complete feeds.

Complete Rations

In recent years, the trend of feeding high levels of concentrate and restricted roughage in complete rations to the dairy animal has produced favorable results. Research has shown that the feeding of complete rations has usually resulted in an increase in milk production and a change in milk composition, particularly in decreasing the milk fat percent (6, 9, 25, 58, 68). This increased milk production has been due primarily to greater energy intake, thus permitting a greater expression of the inherent ability of the cow to produce milk (58, 59, 70). Also, the physical form of the ration fed, such as roughage in a finely ground state, and pelleting (concentrate or entire ration) have been reported to decrease the milk fat content markedly (9, 12, 13, 16, 30, 49, 50). Several research workers (38, 41, 67, 70) have found that in order to maintain fat content at least 30% of a complete ration should consist of roughage.

Many different sources of roughage (alfalfa, hay, cottonseed hulls (CSH), corn cobs, native grass hay)have been used in complete feeds with good results, but there is disagreement as to whether these can maintain milk fat percentage.

Digestibility of Complete Rations

Many methods such as fecal methoxyl groups, fecal nitrogen and forage protein, lignin, and internal and external indicators have been used to determine digestibility of a ration. Chromic oxide, an external indicator, has been used successfully as an aid in determining digestibility, but various problems have been encountered, such as excretion patterns. Bloom et al. (11) found when using chromic oxide as an indicator, the diurnal excretion varied with different ratios of hay to concentrates. This would indicate that the diurnal excretion pattern should be established for each ration. Research by King and Moore (31) has indicated that the larger the particle size, the slower the rate of passage and also that fibrous material would affect the shape of the diurnal excretion curve. Smith and Reid (63) found that feces samples taken at 0600 and 1600 would give a more accurate mean rate of recovery of chromic oxide (100.58 $\pm$ 0.87%) than any other time of sampling. In a study of the excretion pattern of chromic oxide by cows fed a complete feed, McCoy et al. (42) were able to demonstrate that the most accurate mean rate of recovery of chromic oxide (101.9%) was obtained when grab samples were taken at 0800 and 1900.

The effect of concentrate level on ration digestibility has been studied by a number of research workers. Digestibility of rations containing 80, 60, and 40% dry matter from roughages, and the remainder from concentrates has been studied by Putnam and Loosli (54). Using the total collection technique, they found the apparent digestibility coefficients of the dry matter,(68.6 - 65.2%) crude protein (72.4 - 69.8%), ether extract (77.0 - 60.9%), and nitrogen-free extract (74.8 - 70.5%) decreased as the proportion of roughage in the ration increased and that the crude fiber (51.9 - 59.6%) digestibility increased. These findings are in agreement with other research workers (11, 17, 37), however, they have reported a wide range in degree of depression of apparent digestibility coefficient for fiber.

Complete feeds containing 30% roughage and 70% concentrate have been fed ad libitum to lactating dairy cows (41, 67, 70) without a depression in the milk fat percentage. McCoy et al. (42) studied the digestibility of three complete feeds fed ad libitum to lactating dairy cows in a Latin-square change-over design experiment. The coefficients of apparent digestibility (chromic oxide indicator method) for dry matter (DM), crude protein (CP), ether extract (EE), and nitrogen-free extract (NFE) were found to be similar for the complete feeds in which the roughage sources were ground alfalfa-orchard grass hay, corn cobs and CSH. However, the digestion coefficients for crude fiber (CF) were different, with the hay complete feed being the highest (48%) and CSH complete feed (25%) being the lowest.

Villavicencio and Rusoff (71) used sheep to determine the digestibility of complete rations for dairy cattle which contained a 30% roughage source consisting of alfalfa hay (II), CSH (III) or native grass hay (IV), an were compared to a control (I) ration of alfalfa hay and concentrate fed separately. Significant differences ($P < 0.01$) were found between the digestion coefficients for DM (I, 72.9; II, 71.0; III, 62.8; IV, 63.8), CP (I, 68.0; II, 67.0; III, 63.0; IV, 64.0), NFE (I, 84.0; II, 83.0; III, 74.0; IV, 71.0), CF (I, 35.0; II, 31.0; III, 28.0; IV, 40.0), and TDN (I, 63.0; II, 61.0; III, 55.5; IV, 57.0). These digestion coefficients are lower than those obtained by Kromkris et al. (33) and Putnam and Loosli (54), and similar to those of Lovell and Rusoff (39), Bloom et al. (11) and McCoy et al. (42).

Presently there is very limited information on the digestibility of completely mixed rations, although it does appear that the digestibility of these rations will be similar to conventional rations fed at the same high level.

Volatile Fatty Acids (VFA) in the Rumen

Research work by numerous workers (3, 5, 15, 18, 26, 29, 30, 68) have shown that milk fat percentage can be severely depressed by feeding restricted roughage. Jorgensen and Schultz (27) have listed the following procedures that tend to depress milk fat percentage: fine grinding of roughage, pelleting the concentrate or the roughage, and restricting the roughage while feeding high levels of concentrates. They also listed the biochemical changes that occur in the rumen as: a decrease in the proportion of rumen acetic acid, and increase in the proportion of rumen propionic acid, a reduced ratio of acetate to propionate as a result of the two previous changes, and a lowered rumen pH.

In 1963, Van Soest (68) reviewed the theories proposed as explanations for this phenomenon. The first theory involves a deficiency of rumen acetic acid. There is good evidence that diets which cause a reduction in milk fat percentage also tend to narrow the acetate to propionate ratio found in the rumen (9, 23, 24, 30, 56). Work by Spahr et al. (64) has indicated that no advantage could be obtained by feeding a ration which contained less than 16% crude fiber. Variable results have been obtained by feeding acetate salts or acetic acid to cows with low fat percentages (29, 34, 40, 60), but the existance of a real acetate deficiency has also been questioned (68). The second theory involves a reduction in the blood concentration of beta-hydroxybutyric acid (BHBA). Shaw (62) has demonstrated that BHBA is an essential precursor of the short-chain fatty acids in milk fat and Kumar et al. (34) were able to demonstrate the utilization of BHBA by the ruminant mammary gland and the ketogenic activity of butyric acid. The antiketogenic activity of propionic acid has also been demonstrated (61). The third theory involves the endocrine (pancreas, anterior pituitary) control of fat mobilization. It has been suggested by McClymont (44) that increased blood glucose levels suppress the liberation of free fatty acids (FFA) by adipose tissue, thus reducing the plasma lipids available for milk fat synthesis.

Most research workers are in agreement as to the effect of restricted roughage feeding on the VFA found in the rumen, but there is very little agreement as to the different causes and what steps could be taken to make corrections in the depression of milk fat.

Fatty Acids of Milk Fat

Due to its practical importance and academic challenge, the problem of milk fat depression caused by restricted roughage feeding with large amounts of concentrates, has received much attention in the last two decades.

Besides the theories reviewed by Van Soest (68) to explain the metabolic events involved in the reduction of milk fat synthesis, it is known also that the two sources of milk fatty acids, de novo synthesis in the udder and blood lipids, each give rise to different fatty acids in the milk fat. The lower-chain fatty acids ($C \leq 10$) are synthesized in the udder and the longer chain fatty acids ($C > 10$) are derived from the blood lipids, whereas those of medium chain length may arise from both sources (4, 20, 51). Therefore, it should be expected that if milk fat depression occurred as a result of a reduction in any of these precursors of milk fatty acids, a corresponding change would occur in the milk fatty acids and become manifested in the milk fat.

Wisconsin workers (29) have shown that when milk fat-depressing diets were compared to conventional rations, there were decreases in the short-chain as well as the palmitic and stearic acid components, and increases in the unsaturated fatty acid components of the milk fat. California workers (51) reported similar findings when they compared ad libitum feeding of only alfalfa hay or grain, but they found that the magnitudes of the decreases were considerably less for the lower and unsaturated acids than for the higher saturated fatty acids. They also found increased outputs of certain unsaturated and odd-numbered fatty acids. Kunsman and Keeney (35) of Maryland also noted a decrease in saturated and an increase in the unsaturated fatty acids of milk fat produced by cows on a daily diet of 3 lb of hay plus grain in ad libitum quantities.

Despite considerable research there are conflicting data as to the exact cause of milk fat depression when restricted roughage is fed and what means can be used to correct this depression.

Economics (returns above feed costs) of Complete Feeds

In 1966, Leighton (38) reported on an economic study of ad libitum feeding trials with complete dairy rations consisting of 30% alfalfa hay, chopped or ground, and 70% ground sorghum grain. The control ration consisted of alfalfa hay, ad libitum and liberal allowances of a 16% protein concentrate mixture. The daily fat corrected milk (FCM) for the alfalfa hay (chopped), alfalfa hay (ground) and control rations were 34.04, 32.80, and 31.37 lb per day, respectively, and the daily feed costs were $0.83, $0.79, and $0.77, respectively. Daily returns above feed costs were $1.45, $1.46, and $1.42, respectively, for the above rations.

An economic study of dairy farms in Georgia which were feeding a complete feed containing 60% concentrate and 40% roughage was conducted by Welch et al. (74). A sharp increase in milk production and a lowering of milk fat was found in one herd, while another herd of questionable producing capacity failed to increase in production. They found that virtually all cows and heifers placed on this feeding program at least 15 days prior to freshening responded favorably with high milk production and absence of excess body fat; while cows placed on such feeding systems late in lactation usually did not respond with higher milk yield, but with gains in body weight.

Ward (72) reported that when cows were fed a complete feed (40% roughage) as compared to a conventional forage and concentrate ration there were no appreciable differences in milk fat test and the cows on the complete ration seemed to be producing at a somewhat higher level.

Leighton (38) reported that one dairyman in central Texas had favorable results after one year of ad libitum feeding complete feeds to his cows (producing above 15.9 kg milk per day) after switching from a conventional ration. The complete feed consisted of 30% peanut hulls, 50% ground milo, 10% commercial protein concentrate and 10% cottonseed meal.

Leighton (38) recommended to dairymen interested in adopting ad libitum feeding of complete feeds to divide their milking herd, placing only the higher producing cows on full feed; Holsteins producing above 50 lb and Jerseys producing above 30 lb of milk per day. The lower producing cows may be fed the same feed, but on a restricted basis or roughage free-choice and additional concentrates in the milking barn.

To date it does appear that there are a number of commercial farms feeding complete feeds and a number of Feed Manufacturers conducting research in this area, but at the same time there is very little information as to the returns above feed cost for complete feeds. In the final analysis the economic aspects of ad libitum feeding to dairy cows are of primary concern, and the relative feed and milk prices in a specific area are of major concern in any consideration.

EXPERIMENTAL METHODS

Statement of the Problem

Present information indicates that ad libitum feeding of concentrates is not practical, so other feeding practices must be used to supply the nutrients needed for high production and still maintain adequate fat percentage. Also, it appears that some minimum level of roughage or crude fiber is necessary to prevent milk fat depression. In order to realize the genetic potential of dairy cows, maintain adequate fat percentages and overcome the increased cost of labor, roughage, and storage space, there has been renewed interest in complete rations and their effect on milk production and composition.

The objectives of this investigation are: a) to compare the digestibility of complete rations as determined by digestibility trials conducted with fistulated non-lactating dairy cows and lactating cows, b) to determine the effect of complete rations on the fatty acids (C-2, C-3, C-4) found in the rumen and on the fatty acids in the milk fat (C-12 to C-18:3), and c) to determine the economics of the complete rations used.

Rations Used

The experimental complete rations were formulated by using one of three roughages (alfalfa hay or native grass hay chopped to approximately 2.5 cm long, or cottonseed hulls (CSH) as 30% of each ration. Complete rations were compared to the control ration in which alfalfa hay (long stem) was fed separately from the concentrate portion at the same roughage - concentrate ratio of 30:70. The ingredients and composition of the experimental rations can be found in Table 1.

Assignment of Animals

Fistulated Animals: Four rumen-fistulated animals (2 Jerseys and 2 Holsteins) were used to determine digestibility of the experimental rations. They were first placed on a 10-day standardization period where they were fed the control rations (alfalfa hay - long and concentrates separately). At the end of the standardization period they were randomly assigned to the experimental rations.

Lactating Animals: Sixteen Holstein cows having at least one previous lactation record and had been in production for at least 50 days were selected from the Louisiana State University dairy herd. (Table 2). Cows were blocked (Table 2) in groups of four according to stage of lactation, expected 305 2X M.E., and estimated real producing ability (ERPA). Four cows in each block were then randomly assigned to the four experimental rations. The first two blocks (8 animals) became available January 1, 1967 and the second two blocks on January 20, 1967.

Duration of the Experiment

Fistulated Animals: The duration of the digestibility trial was two ten-day periods, the first ten days being the standardization period. At the end of standardization period the four animals were randomly assigned to the four experimental rations.

Lactating Animals: The duration of the feeding experiment was 12 periods of ten days each, the first period being the standardization period,

TABLE 1

Ingredients and Composition of Experimental Rations

Ingredient	Rations I Control	II Alfalfa	III CSH	IV Native Grass
	- - - - - - - - Per Cent	- - - - - - - -		
Soybean oil meal (44%)	5	5	9	10
Cottonseed meal (41%)	4	4	9	9
Ground yellow corn	47	47	38	37
Molasses (cane)	10	10	10	10
Urea (42%)	1	1	1	1
Alfalfa hay (long)	30	-	-	-
Alfalfa hay (chopped to 2.5 cm)	-	30	-	-
Cottonseed hulls	-	-	30	-
Native grass hay (chopped to 2.5 cm)	-	-	-	30
Steamed bonemeal	2	2	2	2
Salt	1	1	1	1
Vitamin A (10,000 IU/g) and Vitamin D (5,000 IU/g)	- - - - - - - 220 g/ton	- - - - - - -		

TABLE 2

Previous History, Pre-experimental Data and Assigned Treatment of the Experimental Animals

Ration[a]	Block[b]	Cow No.	Age Years Month	No. of Records	Days in Lactation	Production to date (kg)	Expected 305[c] 2X M.E. (kg)
I	1	636	4 -- 10	2	84	2516	6712
	2	479	9 -- 0	4	96	2628	6165
	3	632	5 -- 0	2	58	1806	7178
	4	567	6 -- 11	4	76	2285	6808
II	1	562	7 -- 0	3	60	1827	6833
	2	679	4 -- 0	1	63	1772	6486
	3	623	5 -- 3	2	68	2089	7054
	4	667	4 -- 4	2	52	1614	7287
III	1	699	3 -- 2	1	111	3272	7673
	2	656	4 -- 5	2	58	1383	5278
	3	634	4 -- 11	2	71	2107	6922
	4	650	4 -- 7	1	53	1575	6848
IV	1	588	6 -- 3	2	92	3272	7821
	2	649	4 -- 6	1	109	2380	5086
	3	631	5 -- 0	2	66	2159	7506
	4	696	3 -- 6	1	73	1716	5957

[a]I = Alfalfa hay long stem fed separate from concentrate; II = 30% alfalfa hay chopped to 2.5 cms, and 70% concentrate; III = 30% cottonseed hulls and 70% concentrate; IV = 30% native grass hay and 70% concentrate.

[b]Animals were assigned to blocks on Jan. 10, 1967 for blocks 1 and 2, and Jan. 30, 1967 for blocks 3 and 4.

[c]Expected 305 was calculated after animals had been on standardization period (10 day), Jan. 10, 1967 for blocks 1 and 2, and Jan. 30, 1967 for blocks 3 and 4.

animals were assigned to their respective ration according to standard procedures (65) and each animal remained on its ration for the remainder of the study.

Feeding and Care of the Animals

Management: The fistulated cows were kept in individual stanchions under one end of open on stanchion barn where individual mangers and water cups were provided. Sugar cane bagasse was used for bedding and was replaced as needed.

The lactating cows were kept in individual free stalls under an open barn where individual mangers and water cups were provided. Animals were restrained in individual free stalls except for the time they were being milked (0700 and 1700) and a four-hour exercising period (1100-1500) in which they were turned loose in the loafing lot. Three-foot chains were used to retain the cows in the free stall in which wood shavings were used for bedding.

Feeding: In an effort to obtain true ad libitum feeding, feed was offered three times daily (0800, 1300, and 1800). The fistulated animals were fed in the mangers and daily feed consumption was determined. The lactating cows on ration II, III, IV were fed by individual bins adapted with manual dispensers. These bins were kept full at all times and a record of daily feed was taken. At the end of each ten-day period, all bins were emptied, and the weight of the feed left in the bins was entered as refused. Feed refusals for the control group were weighed prior to each morning feeding. In order to insure proper ad libitum feeding, feed allowance was offered daily to provide feed refusals of 10 - 15%. Additional salt and a mineral mixture (steamed bonemeal) were provided in the loafing lot for free-choice consumption.

Collection of Data

Feed Intake: Individual daily feed consumption was determined and separated into roughage and concentrate constituents. For the control group, the roughage and concentrate were fed separately, therefore, the weigh-backs were recorded separately as roughage and concentrate. Samples of feed offered and refused were taken daily and from them an aliquot sample was taken for chemical analysis.

Chemical Analysis of Rations and Feces: Composited samples of feed and feces were analyzed by proximate analysis (2) with CP being determined on a fresh sample of feces. Duplicate air-dried samples of feed and feces were burned in a Parr Adiabatic bomb calorimater to determine gross energy. Approximately one gram of sample was burned and digestible energy (DE) was determined.

Digestibility Studies: Digestibility of the experimental rations were determined using the total collection method (3 days) on the fistulated cows and the chromic oxide indicator method on both the fistulated and lactating animals (period 6 and 8). Ten grams of chromic oxide were fed to each animal during a five-day preliminary period and a three-day collection period. The chromic oxide was mixed with 1 kg of concentrate and fed at 0800. Fecal grab samples were taken from the fistulated cows every two hours during the three-day collection period to determine chromic oxide excretion pattern, and from the lactating cows at 0900 and 1900 daily. Fecal samples were placed in plastic bags and stored at -20C until the end of the collection period, after which they were removed, composited and analyzed.

Digestion Coefficients and TDN: Digestion coefficients for DM, CP, CF, EE and NFE were determined on the fistulated and lactating animals. Digestibility of the rations were determined on the fistulated animals using the chemical analyses of the feed and feces, and the data from the total collection trial. The relative per cent of recovery of chromium was obtained by determining the mean parts per million (ppm) of chromium per gram of DM of the twelve fecal samples, collected at two hour intervals for each cow. With this mean being 100% recovery, then any deviation about this figure would be the diurnal variation for each ration. To determine digestibility of the rations using the lactating animals, the chromic oxide indicator method was used. Chromium concentration was determined on a one gram sample using a Perkin-Elmer Atomic Absorption Spectrophotometer (53). Digestibility was determined using the following formula:

$$\text{Digestibility} = 100 - \left[100 \quad \frac{\%\ \text{Cr in feed}}{\%\ \text{Cr in feces}} \times \frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in feed}} \right]$$

In order to determine digestible energy it was necessary to use the following formula to calculate fecal output for the lactating animals:

$$\text{kg feces per day} = \frac{\text{dry matter consumption} \times \%\ \text{Cr in feed}}{\%\ \text{Cr in feces}}$$

Total digestible nutrients (TDN) were determined using the digestion coefficients obtained for CP, CF, EE (x 2.25) and NFE.

Collection and Preparation of Rumen Fluid Samples: Rumen fluid samples were collected from four rumen-fistulated animals for three consecutive days at 0, 2, 4, and 6 hours after feeding. The samples were strained through cheese cloth immediately following collection and placed in a centrifuge and subjected to a force of 2,000 g for a period of fifteen minutes. Fifty milliliter (ml) of the supernate were removed from the samples, preserved with saturated mercuric chloride (0.5 ml per 20 ml of rumen fluid) and stored at - 20C for future extraction of volatile fatty acids (VFA). Fifteen milliliters aliquots were taken for VFA analysis, and were extracted and prepared after the method of Conrad (14) with modifications as suggested by Larson (36). This procedure consisted of a simple extraction at acidified sample pH 1.00, with sufficient ethyl ether to prevent the formation of an emulsion. The modification of Conrad's method consisted of the substitution of a twenty-five ml graduated cylinder for the separatory funnel. The fifteen ml samples were placed in cylinders and to each was added 1.5 ml of 4 N $H_2 SO_4$. Ten ml of ethyl ether was added and the contents thoroughly mixed. Capillary pipettes were used in drawing off approximate 3 ml portions of the ether phase. Samples were then treated with sufficient amounts of sodium sulfate to insure removal of water prior to injection into the gas chromatograph. The instrument used in determining the ratio of volatile fatty acids produced was a Micro-Tek, GC 1600. The column used consisted of a 20% diethyleneglycol succinate and 2% phosphoric acid mix packed on 80 - 100 mesh chromoport. Flow rate of the carrier gas, helium, was adjusted to 65 ml per minute and the oven temperature was set at 150 C. Five microliter aliquots of each sample were injected at approximately 25 minute intervals. Charts were tabulated, assuming acetic, propionic and butyric acids as 100% of total acid production. Peak areas for the individual acids were computed using the integrator and results expressed in area % of total acid production.

<u>Collection and Preparation of Milk Fat Samples</u>: Milk was collected during periods 4, 6, 8, 10, and 11 for analyses of the fatty acids found in the milk fat. Fat was extracted from 35 ml of milk using 10 ml of BDI reagent (a mixture of a non-ionic surfactant and sodium tetraphosphate, "calgon", in water). The extracted fat was placed in 3 ml ampules, sealed under nitrogen and stored at - 20C for future saponification and methylation of fatty acids. Methylation was accomplished according to the method used by Ways *et al*. (73). Gas chromatographic analysis of methyl esters was performed on a Micro-Tek Model GC chromatograph equipped with a glass column (2 m x 5 mm) packed with 15% ethylene glycol adipate on 60 - 80 mesh chromosorb W (Micro-Tek, Inc., Baton Rouge, La.). A column temperature of 200 C was maintained with the helium gas flow rate of 60 cc/min., a hydrogen flow rate of 40 cc/min and an air flow rate of 0.8 cc/min. Identification of peaks of fatty acids was based on retention times relative to those of known fatty acids. The area of each peak was calculated using the integrater and reported as per cent of total peak areas.

<u>Economics of Complete Feeds</u>: Daily feed cost, feed costs/kg FCM and daily returns above feed cost were determined using actual cost of ingredients to the L.S.U. Department of Dairy Science.

<u>Statistical Analysis</u>: Analysis of variance according to the method of Steele and Torrie (65) were conducted to test the significance of any differences obtained from the rations. The design of the lactation experiment was a continuous trial (120 days) with 16 cows assigned to four randomized blocks with a split-plot in time. The design of the fistulated cow experiment was a randomized design with 4 cows assigned to four treatments and observations taken at 0, 2, 4, and 6 hours after feeding.

RESULTS AND DISCUSSION

Chemical Analysis of Rations

The calculated chemical analyses from Morrison (47), actual chemical analyses, and chemical analyses of ingredients used the experimental rations are presented in Tables 3, 4, and Appendix Table 1a, respectively. The calculated and actual CP values were found to be quite similar for rations I, II and III, while the calculated CP slightly over-estimated the actual CP for ration IV. Calculate CF for rations I, II and IV under-estimated the actual CF and over-estimated actual CF for ration III. The calculated DM was similar to the actual DM for all rations and as a whole, the chemical analyses of the experimental rations indicated that they were very similar.

Digestibility Studies

Excretion Pattern of Chromium Ion: The diurnal excretion patterns of chromium ion for the experimental rations fed to the rumen-fistulated cows are shown in Figure 1, and the relative per cent recovery of chromium ion has been presented in Appendix Table 2a. These curves are based on the percentage recovery of chromium ion in the 12 two-hour grab samples. The mean rate of recovery for chromium ion on the different treatments at the collection times of 0900 and 1900 were I-94.4%, II-102.2%, III-98.9%, and IV-99.7%. Although considerable variation existed between the individual curves, the average recovery rate (0900 and 1900) for all rations was 98.8%. These results are in close

TABLE 3

Calculated Chemical Analyses of the Experimental Rations[a]

Nutrient	Rations I Control	Rations II Alfalfa	Rations III CSH	Rations IV Native Grass
	- - - - - - - -	Per Cent	- - - - - - - -	
Crude Protein	15.86	15.86	15.71	17.12
Crude Fiber	10.24	10.24	15.75	11.90
Dry Matter	86.22	86.22	85.94	86.30
TDN	65.00	65.00	62.39	64.65

[a]Morrison's Tables (47), 90% DM.

TABLE 4

Chemical Analyses of the Experimental Rations[a]

Nutrient	Rations I Control	Rations II Alfalfa	Rations III CSH	Rations IV Native Grass
	- - - - - - - -	Per Cent	- - - - - - - -	
Crude Protein	15.95	15.95	15.93	16.31
Crude Fiber	11.32	11.32	12.76	12.47
Ether Extract	2.00	2.00	2.27	2.60
NFE	49.46	49.46	49.24	47.76
Ash	6.67	6.67	5.37	7.46
Dry Matter	85.40	85.40	85.57	86.60

[a]Average of 10 chemical analyses.

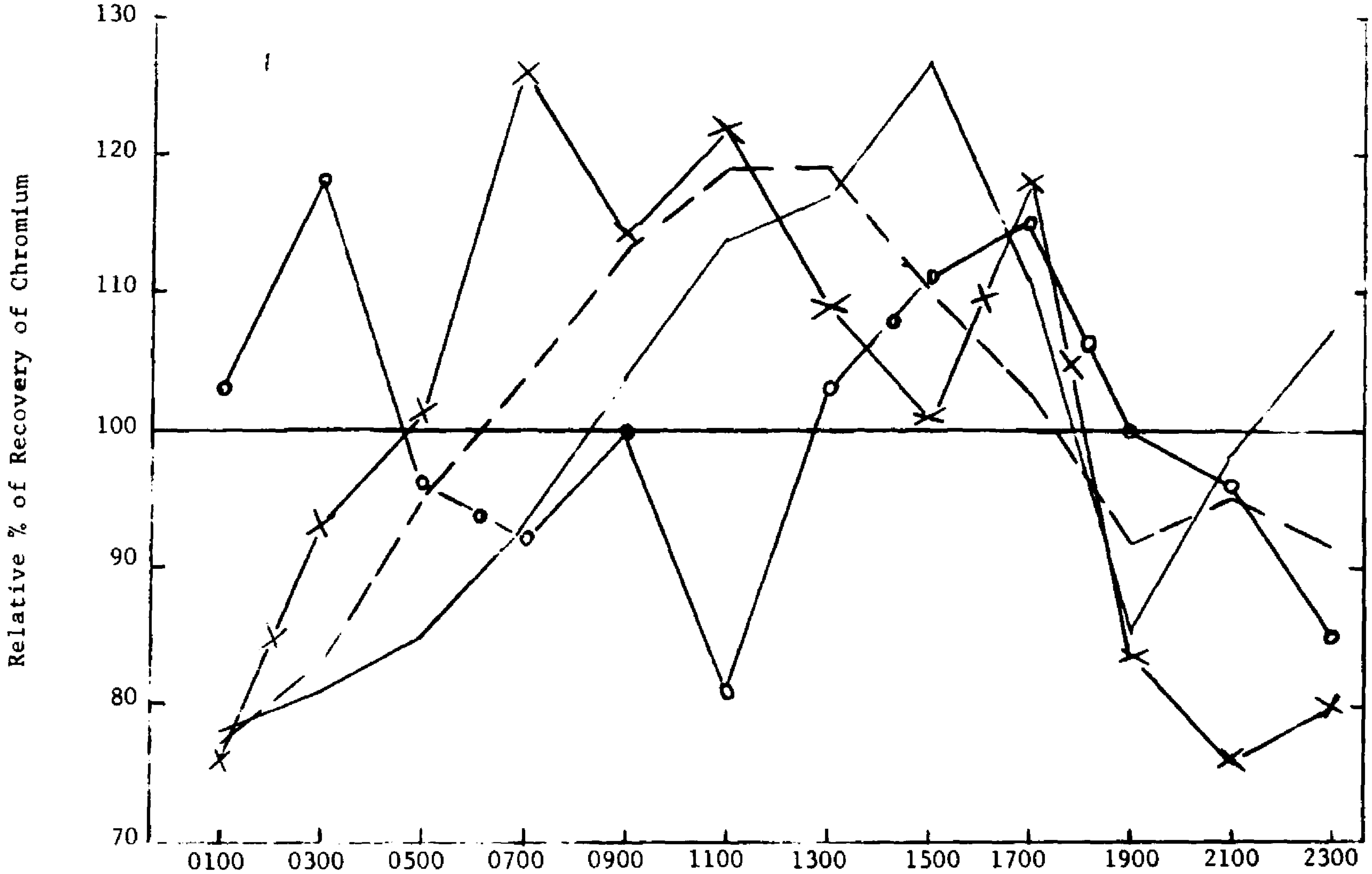

Figure 1. Diurnal Excretion Pattern of Chromium Ion When Administered at 0800 Daily by Rumen-Fistulated Animals Fed Experimental Rations.

——— Ration I, - - - - - Ration II, —X— Ration III, —O— Ration IV agreement with those reported by McCoy <u>et al</u>. (42), who use similar times for collection and found a relative percentage recovery rate of 101.9%. Some of the observed variation between the excretion pattern of chromium ion (Figure 1) was due to animal differences, since there was only one animal per experimental ration (grab samples taken on three consecutive days from each animal).

<u>Total Collection Trial with Rumen-Fistulated Animals:</u> A summary of the responses obtained with the rumen-fistulated non-lactating dairy animals is given in Table 5. No problems were encountered in the consumption of the experimental rations, although the animal on the native grass hay ration consumed considerably less than the other animals. The highest consumption of feed occurred on the cottonseed hull ration (Table 5). The Therms per kg of feed and per kg of feces were found to be, (I) 4.25, 3.90; (II) 4.16, 4.05; (III) 4.08, 4.21; and (IV) 4.06, 3.65, respectively. The feces from the animal on the cottonseed hull ration had the highest caloric value (4.21 Therms), which would suggest lower digestibility.

On a gross energy basis (Table 5) it appears that the rations had approximately the same energy value (4.25 - 4.06 Therm/kg), but when the Therms of DE/kg of feed were compared there were large differences. The Therms of DE/kg of feed for the experimental rations were found to be, I-3.08, II-2.97, III-2.68 and IV-2.73. These values are similar to those reported by Villavicencio and Rusoff (71) who found them to be 3.13, 2.93, 2.49 and 2.57 Therms, respectively, using sheep fed the same rations. To obtain the DE/kg feed, the digestion coefficients (Table 5) for each ration were multiplied by their respective Therms per kg of feed.

TABLE 5

Summary of Responses Obtained from Digestibility Trial (Total Collection) with Rumen-Fistulated Non-lactating Dairy Animals Fed Experimental Rations

	Rations			
	I Control	II Alfalfa	III CSH	IV Native Grass
Observation				
Av. daily feed intake (kg)	16.67	16.67	17.42	11.14
Av. daily feed intake (ADB,kg)[a]	15.76	15.71	16.57	10.71
Therms per kg of feed	4.25	4.16	4.08	4.06
Av. daily feces excreted (kg)	20.45	21.89	17.94	17.74
Av. daily feces excreted (ADB,kg)	4.43	4.63	5.54	3.90
Therms per kg of feces	3.90	4.05	4.21	3.65
Digestible energy/kg feed (Therms)	3.08	2.97	2.68	2.73
Digestion Coefficients (%)				
Digestible energy	72.37	71.29	65.57	67.22
Dry matter	71.88	70.50	66.57	63.63
TDN	60.66	59.92	56.49	55.05
Crude Protein	67.61	66.42	64.43	61.81
Crude Fiber	39.23	43.88	24.67	43.00
Ether extract	65.47	79.18	87.12	83.64
NFE	83.28	82.49	78.44	72.69
Energy and TDN Intake				
Gross intake (Therms)	66.98	65.35	67.61	43.48
Fecal Output (Therms)	17.28	18.75	23.32	14.24
Digestible energy intake (Therms)	49.70	46.60	44.29	29.24
TDN intake (kg)	9.56	9.41	9.36	5.90

[a]ADB : air-dry basis or 90% dry matter.

The DE and TDN coefficients (Table 5) of the experimental rations were found to be (I) 72.37, 60.66; (II) 71.29, 59.92; (III) 65.57, 56.49; and (IV) 67.22, 55.05, respectively. Digestible energy coefficients for the control ration (72.37%) and alfalfa ration (71.29%) were similar while the values were much lower for the cottonseed hull ration (65.57%) and native grass ration (67.22%). Although the cottonseed hull ration had the lowest DE coefficient, it had the greatest average feed consumption which made the intake of DE (44.20 Therms) similar to that of the alfalfa ration (46.60 Therms) and greater than that of the native grass hay ration (29.24 Therms). The control ration had a slightly higher DE coefficient and DE intake than the alfalfa ration which was probably due to the fact that the animal on the control ration ate slightly more than 70% concentrate while the animal on the complete feed consumed exactly 70%.

The CF digestion coefficients (Table 5) for the control, alfalfa ration and native grass hay ration were similar (39.23 - 43.88) while the coefficients for the cottonseed hull ration was approximately half (24.67) of the values of the other three rations. Similar digestion coefficients for CF have been reported by Villavicencio (70) and McCoy et al. (42). Highest digestion coefficients for EE (Table 5) were found for the cottonseed hull ration (87.12%) and native grass hay ration (83.64%), and lowest NFE values, (78.44% and 72.69%), respectively.

Indicator Method with Lactating Animals: The results of the digestibility trials (periods 6 and 8) using chromic oxide is presented in Table 6. It can be noted that the average daily feed intake (22.24 - 26.15 kg) for the lactating dairy cows was greater than the average

TABLE 6

Summary of Responses Obtained from Digestibility Trials (Chromic oxide) with Lactating Animals Fed Experimental Rations

	Rations			
	I Control	II Alfalfa	III CSH	IV Native Grass
Observation				
Av. daily feed intake (kg)[a]	22.24	23.73	26.15	23.53
Therms per kg of feed	4.25	4.16	4.08	4.06
Av. daily dry matter excreted (kg)[a,b]	6.89	7.19	9.38	9.29
Therms per kg feces	3.91	4.01	4.07	3.91
Digestible energy/kg feed (Therms)	3.04	2.95	2.63	2.53
Digestion Coefficients (%)				
Digestible energy	71.47	70.86	64.46	62.21
Dry matter	69.06	69.73	63.96	60.77
TDN	57.35	55.93	53.63	52.46
Crude protein	65.80	68.35	66.89	62.46
Crude fiber	45.59	44.77	25.28	42.87
Ether extract	66.78	69.23	69.86	72.72
NFE	78.22	77.66	72.89	68.40
Energy and TDN Intake				
Gross intake (Therms)	94.52	98.72	106.69	95.53
Fecal output (Therms)	26.94	28.83	38.18	36.32
Digestible energy intake (Therms)	67.58	69.89	68.51	59.21
TDN intake (kg)	12.75	13.27	14.02	12.34

[a]ADB: air-dry basis or 90% dry matter.

[b]Dry matter excreted = $\frac{\text{Cr \% x Dry matter intake}}{\text{Cr \% in Feces}}$.

intake of the rumen-fistulated cows (11.14 - 17.42 kg, Table 5). The lactating cows on the native grass hay ration had similar intakes to the animals on the control and alfalfa rations, while those on cottonseed hull ration showed the greatest intake. The Therms DE/kg feed for the lactating animals on the experimental rations (I-3.04, II-2.95, III-2.63, IV-2.53) were in close agreement to that of the rumen-fistulated animals (I-3.08, II-2.97, III-2.68, IV-2.73). Similar values were found by Villavicencio (70) when sheep were fed the same rations.

DE coefficients were found to be slightly lower for all rations when they were determined with the lactating animals as compared to values obtained with rumen-fistulated animals (Tables 5 and 6). Similar DE coefficients (62.48 - 73.32%) were reported by Flatt (19) when he reviewed energy metabolism studies from 1905 to 1963. It is of importance to point out that the average DE intake reported by Flatt (19) was 31.05 Therms with a range of 11.84 to 52.9 Therms, while the DE intake of the lactating cows in this study (Table 6) for the experimental rations were found to be I-67.58, II-69.89, III-68.51 and IV-59.21 Therms. The high levels of production in this study may account for the increased consumption of DE. A comparison of DE coefficients for the experimental rations used in this study as determined by different methods is given in Table 7. Some variations existed between the different methods but as a whole they were very similar with the exception of those for the cottonseed hull and native grass hay rations. These two rations were difficult to sample properly, especially the native grass hay ration since it was very bulky, therefore this might account for some of the observed variations of the experimental rations. Blaxter and Wainman (10) observed

TABLE 7

Comparison of Digestible Energy Coefficients Determined by Different Methods

	Rations			
Method	I Control	II Alfalfa	III CSH	IV Native Grass
	- - - - - - - - Per Cent - - - - - - - -			
Total collection (sheep)[a]	73.8	70.5	61.0	63.3
Total collection (rumen-fistulated cows)	72.4	71.3	65.6	67.2
Chromic oxide (lactating cows)	71.5	70.9	64.5	62.2

[a]Villavicencio and Rusoff (71).

TABLE 8

Comparison of TDN Coefficients Determined by Different Methods

	Rations			
	I Control	II Alfalfa	III CSH	IV Native Grass
	- - - - - - - - Per Cent - - - - - - - -			
Estimated[a]	65.0	65.0	62.4	64.7
Total collection (sheep)[b]	63.0	61.0	55.5	57.0
Total collection (rumen-fistulated cows)	60.7	59.9	56.5	55.1
Chromic oxide (lactating cows)	57.4	55.9	53.6	52.5

[a]Morrison's tables (47).

[b]Villavicencio and Rusoff (71).

similar digestibilities (DE) for sheep and cattle when the plane of nutrition was increased from slightly less than maintenance to twice that amount.

The TDN values of the experimental rations using lactating animals has been presented in Table 6, and a comparison of these values with TDN obtained on the same rations using different methods of determination is given in Table 8. When the TDN coefficients are compared, the TDN values otained using lactating animals were found to be considerably lower than those obtained by estimation (Table 3), the fistulated-animal trial (Table 5) and the sheep trial (71). These values are also lower than those obtained by McCoy et al. (40, 41) for complete feeds. The average daily FCM production by the lactating cows on the experimental rations during the digestibility trial (periods 6 and 8) were I-22.2 kg, II-23.1 kg, III-20.4 kg, IV-17.0 kg, which is considered a relatively high level of production. When the above production levels and the TDN values (Table 8) are considered, a fair assumption would be that it would be incorrect to determine the TDN of a ration with non-lactating animals and extrapolate this information to lactating animals producing at high levels. On the other hand, it would appear that similar DE coefficients could be obtained from lactating or non-lactating animals fed ad libitum (Table 7).

The average daily FCM production of all lactating animals on all rations for the entire study (120 days) was 21 kg and the average body weight was 582 kg. A cow of this weight and production needs approximately 10 kg of TDN per day according to Morrison (47), yet the animals in this study consumed 12.3 to 14.0 kg TDN/day. It is apparent that these animals consumed in excess of their requirements for production and maintenance providing Morrison's Standards are an accurate estimate of their requirements. The TDN intake of these animals are considerably higher than those reported by other investigators (8, 39, 67).

TDN Requirements for Production: Requirements for cows producing at different levels of production on the experimental rations are found in Table 9. These requirements were obtained by determining the requirement for production after maintenance for each cow for the entire experiment on a period (10 day) basis using Morrison's Standards (47). The cows were grouped according to the different production levels shown, and the average requirement determined for each level of production. From the figures shown in Table 9, it can be seen that the high levels of production required the least amount of TDN per kg of FCM produced when animals were fed ad libitum. The average kg of FCM and kg of TDN requirement for production rations were: (I) 22.5, 0.41; (II) 23.4, 0.38; (III) 20.9, 0.51; (IV) 17.5, 0.44, respectively. Animals on ration II had the highest FCM production and were the most efficient converters of TDN into milk. Thurmon et al. (67) postulated that the mixing of chopped hay with concentrates might result in better feed utilization than the feeding of long hay and concentrates separately. The requirements for production obtained in this study are lower than those obtained by Villavicencio and Rusoff (71) and higher than those obtained by Moe et al. (46), and Reid (58, 59).

Results of this study indicate that calculated TDN and DE values using Morrison's Tables tend to over-estimate those obtained in the

TABLE 9

TDN Requirements Per kg FCM for Different Levels of Production for the Experimental Rations Fed Ad Libitum to Lactating Animals[a]

kg FCM	Rations I Control	II Alfalfa	III CSH	IV Native Grass
	- - - - - - - -	- - - - (kg)	- - - -	- - - - - - - -
32-34	.33 (1)[b]	.30 (1)		
29-31	.35 (8)	.32 (3)	.38 (1)	.36 (1)
26-28	.34 (5)	.36 (9)	.42 (7)	.36 (4)
23-25	.43 (10)	.40 (18)	.43 (13)	.37 (9)
20-22	.38 (13)	.42 (8)	.46 (7)	.37 (1)
17-19	.43 (8)	.31 (5)	.43 (4)	.38 (4)
14-16	.55 (4)	.35 (4)	.55 (4)	.48 (7)
11-13			.74 (4)	.49 (14)
8-10			.81 (4)	.51 (4)
Average	.41 (48)	.38 (48)	.51 (44)	.44 (44)

[a]Calculated using TDN of 57.4, 55.9, 53.6, 52.5 for rations I, II, III and IV, respectively.

[b]No. of 10 day periods that animals produced at given level.

digestibility studies using fistulated non-lactating cows and lactating cows. The excretion patterns of chromium ion were found to be in fair agreement for the animals on the different rations and good recovery could be obtained by using collection times of 0900 and 1900. High producing animals fed ad libitum were more efficient converters of TDN into FCM than the same animals fed ad libitum at the lower levels of production. Current feeding practices at present are to supply adequate energy during the dry period immediately prior to calving, rather than supplying excess dietary energy during late lactation. As a result of this practice it is not unusual for cows to lose 45.4 to 90.8 kg of body weight during the first 75 days after calving and some cows have lost as much as 181.6 kg (57). As a result of this loss in body weight, animals will usually gain weight in mid- and late lactation, thus replacing the body stores of energy lost at parturition and used in early lactation. The average gains in weight by the animals on the different rations in this experiment (120 days) were: I-60 kg, II-66 kg, III-74.4 kg, and IV-46.8 kg. Excessive deposition of body weight may be uneconomical, but experimental data are lacking on the efficiency with which this is accomplished during lactation as compared to when the cows are dry. The efficiency of lipogenesis in lactating animals may be greater than when the same animals are dry.(2, 22).

Ration Effects on Rumen VFA

The effect of rations on the concentration of rumen acetic, propionic, and butyric acids (Appendix Table 3a) and their level as a function of time after feeding is shown in Figures 2, 3, and 4. Ration

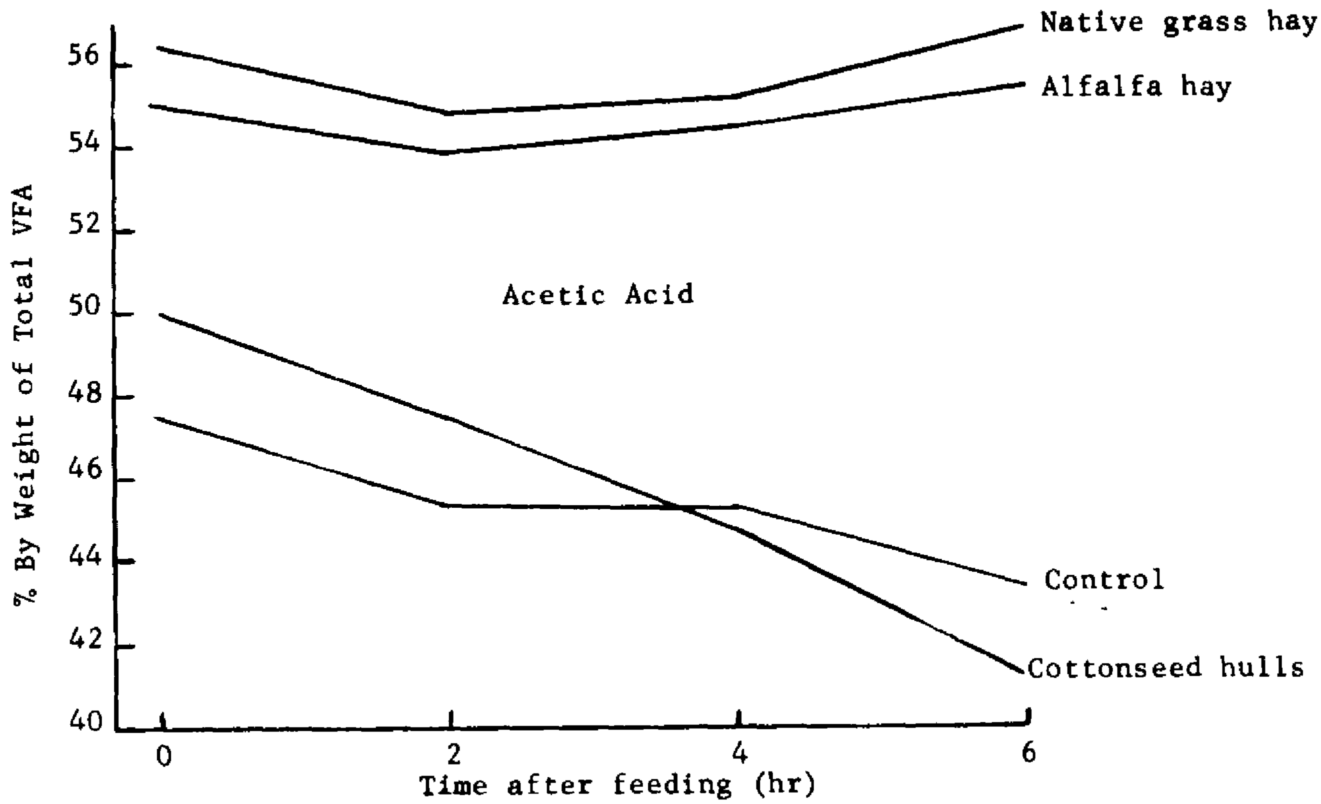

Figure 2. Proportion of acetic acid of volatile acids in the rumen-fistulated animals as affected by rations and time of sampling after feeding.

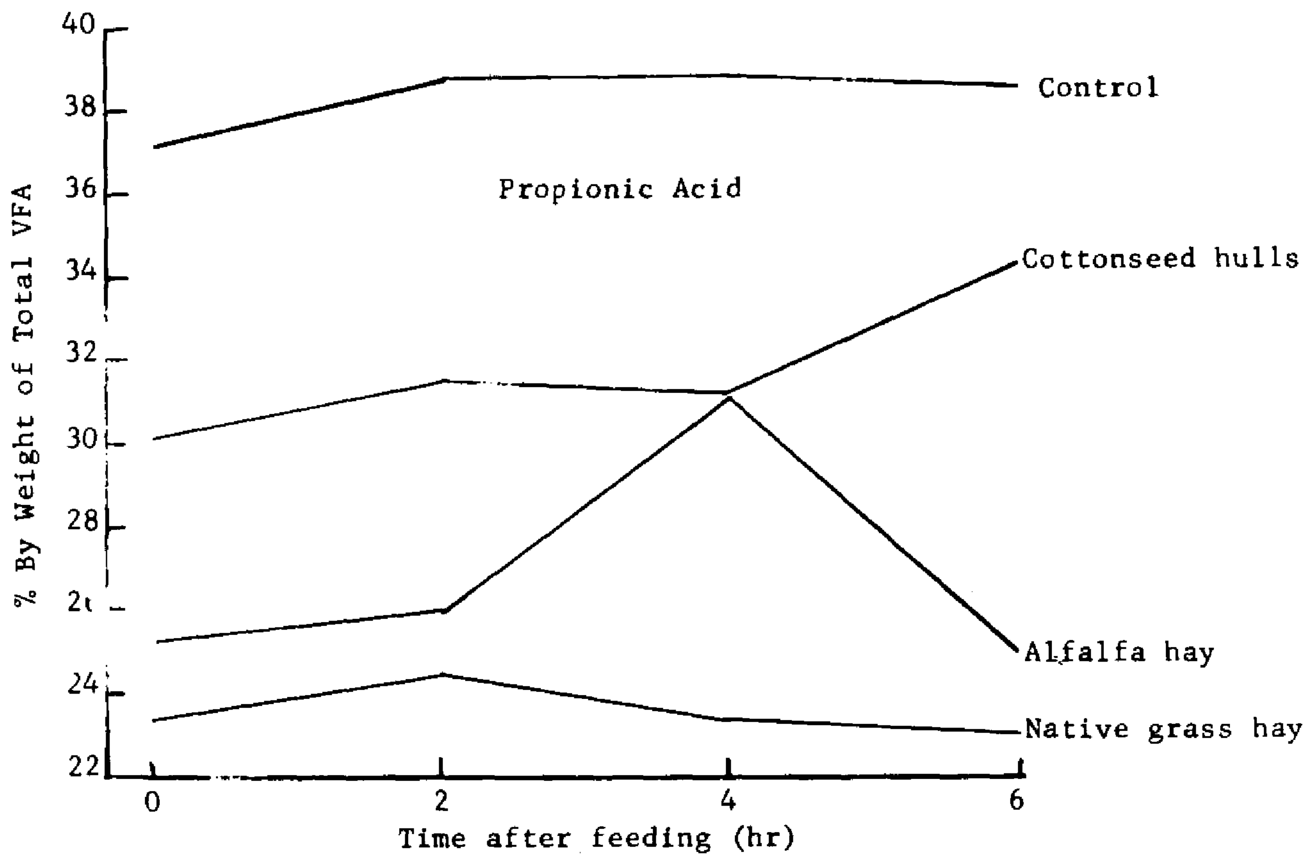

Figure 3. Proportion of propionic acid of volatile acids in the rumen-fistulated animals as affected by rations and time of sampling after feeding.

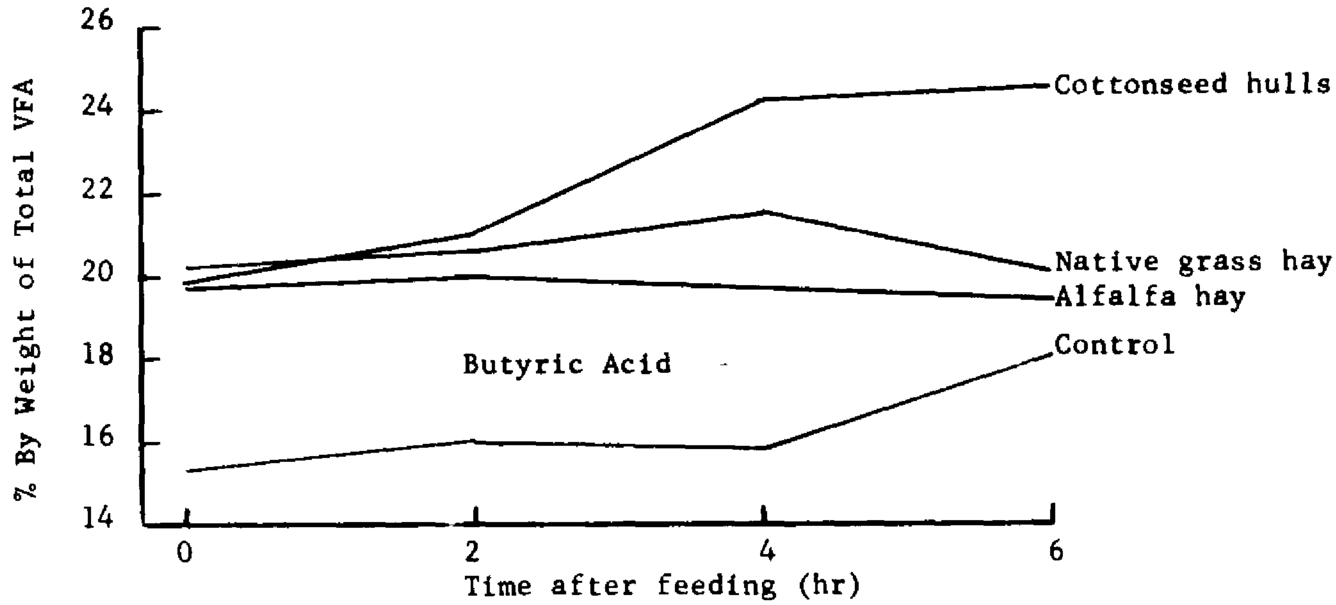

Figure 4. Proportion of butyric acid of volatile acids in the rumen-fistulated animals as effected by rations and time of sampling after feeding

effects were found to be significant for acetate ($P<0.01$), propionate ($P<0.05$) and butyrate ($P<0.01$) levels (Appendix Table 4a). Acetate levels (Figure 2) decreased 2 hours after feeding for all rations and continued to do so for the control and cottonseed hull rations, while the levels for the alfalfa ration and the native grass hay ration increased. Similar levels of rumen acetate were also found by several research workers (15, 18, 26, 27, 28, 29) when restricted roughage was fed. The variation in the acetate levels in this study may be due to the low CF digestibility for ration III and the fact that in the control ration the concentrate and hay were fed separately, thus allowing the concentrate portion to be consumed before the roughage allowance. Low levels of rumen acetate have been found to be associated with low milk fat per cent as reported by other workers (15, 18, 21, 26, 27, 28, 29, 33, 34, 68). This may be one of the explanations for the failure of the control and cottonseed hulls rations to maintain the milk fat percentage after the standardization period.

The control and cottonseed hull rations had the highest levels of rumen propionate (Figure 3) which increased after feeding while the propionate level decreased as a function of time for the alfalfa and native grass hay rations. Similar results have been reported by Knox et al. (32) and Stewart et al. (66). The butyric acid levels (Figure 4) remained quite constant after feeding for the alfalfa and native grass hay rations, while the butyric acid level increased betwen 4 and 6 hr after feeding for the control and cottonseed hull rations. Data from this study indicate that the rumen acetate and propionate levels are influenced to a greater extent by the experimental rations than was the butyrate level.

The statistical design of the rumen-fistulated animal trial is subject to criticism because of only one experimental animal per treatment. A design of this type has no valid error term because effects due to rations and animals are confounded.

Ration Effects on Milk Fatty Acids

The effect of the experimental rations on the fatty acid composition (C-12 to C-18:3) of the milk fat is given in Table 10. A sample of the gas-liquid chromatogram of methyl esters prepared from fatty acids found in the milk fat is presented in Figure 5. Blocking of cows was not effective ($P<0.05$) in removing sources of variation for the C-14:1, C-15, C-16 and C-18:1 fatty acids (Table 11). Significant ration effects (Table 11) were found for C-14:1 and C-15 ($P<0.05$), and for C-18 and C-18:3 ($P<0.01$). Although significant differences were found for these fatty acids, no uniform changes were observed for any of the fatty acids. Under the conditions of this study no definite trends or changes in fatty

TABLE 10

Effect of Experimental Rations on the Fatty Acid Composition of the Milk Fat Produced

Carbon Number	Rations I Control	 II Alfalfa	 III CSH	 IV Native Grass
	- - - - - - Per Cent[a]			- - - - - - -
12	7.23[b]	6.51	6.53	6.13
14	15.99	13.97	14.84	14.34
14:1	2.78	2.40	2.21	2.27
15	2.47	2.20	2.09	1.89
16	27.28	27.26	25.43	25.28
16:1	2.49	3.20	2.85	2.39
17	1.09	0.87	0.81	0.72
18	8.69	10.15	11.42	13.84
18:1	26.08	27.11	27.54	27.22
18:2	5.88	5.43	6.33	5.87
18:3	0.46	0.31	0.10	0.06

[a]Relative per cent of the fatty acids measured.

[b]Average of 5 collection periods with 4 animals per ration.

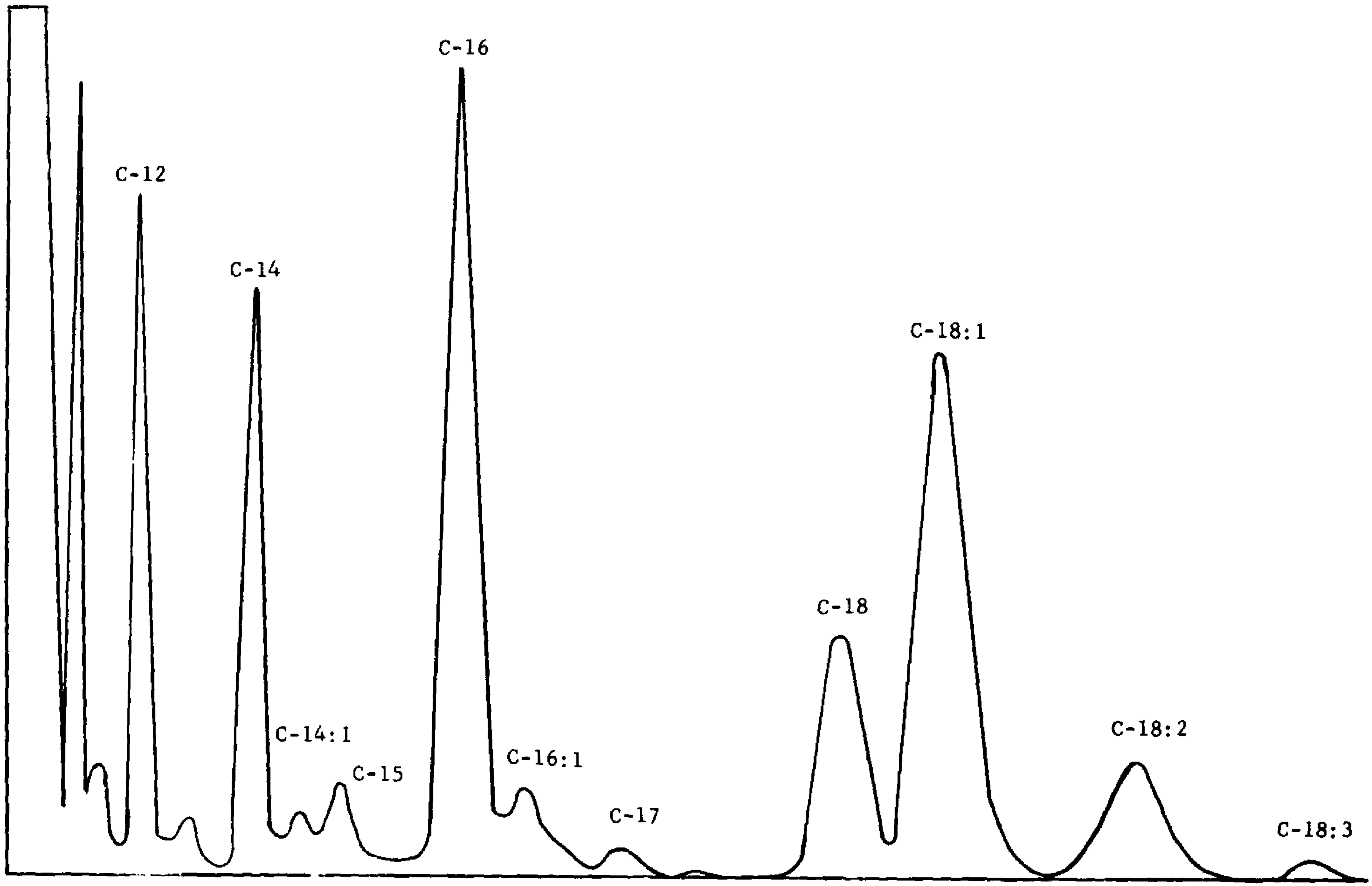

Figure 5. Gas-Liquid Chromatogram of methyl esters of fatty acids in the milk fat.

TABLE 11

Significance of Variance Sources for the Fatty Acids Found in the Milk Fat From the Lactating Cows Fed the Experimental Rations

Variance Source	d.f.	Carbon Number										
		12	14	14:1	15	16	16:1	17	18	18:1	18:2	18:3
Total	79											
Blocks	3	NS	NS	*	*	*	NS	NS	NS	*	NS	NS
Rations	3	NS	NS	*	*	NS	NS	NS	**	NS	NS	**
Error A	9											
Periods	4	**	**	*	NS	**	**	NS	**	**	**	*
Rations x Periods	12	NS	NS	NS	NS	*	NS	*	NS	NS	*	*
Error B	48											

NS - Not Significant
* - Significant at $P < 0.05$.
** - Significant at $P < 0.01$.

acid content were found. It is interesting that significant differences in the concentrations of fatty acids for periods were found for C-12, C-14, C-16, C-16:1, C-18, C-18:1, C-18:2 ($P<0.01$) and for C-14:1 and C-18:3 ($P<0.05$). This would indicate that as lactation progressed there were changes that occurred, but no specific changes could be observed. Various research workers (29, 35, 51) have been able to demonstrate changes in the fatty acid content of milk from cows on milk fat-depressing rations, but under the conditions of this study no trend was observed.

Some variations in the concentrations of fatty acids were noted when compared to results in the literature (5, 29, 35, 51). These variations might be due to instrumental techniques and conditions under which gas chromatographic analysis were carried out. Methylation reagents, time and temperature also affect the completion of methyl ester preparation as described by Patton _et al_. (52).

Economics (returns above feed costs) of Complete Feeds

A summary of the performance of the lactating cows fed the experimental rations for 120 days is given in Table 12, and the cost of the rations and ingredients are presented in Appendix Table 5a. This study was initiated January 1, 1967 and at this time the cost of cottonseed hulls was \$.0468/kg (\$2.10/45.4 kg or 100 lb) which was relatively high when compared to the cost of alfalfa hay (\$.0468/kg or \$2.13/45.4 kg). If storage facilites had been available, the cost of the cottonseed hulls ration could have been lowered by buying at their lowest price and storing them until needed. The cost of the control, alfalfa, cottonseed

TABLE 12

Summary of Performance Data for Lactating Animals Fed Experimental Rations for 120 Days

	Rations			
Performance Data (per cow)	I Control	II Alfalfa	III CSH	IV Native Grass
Hay (kg/day)	6.83	6.42	8.03	6.65
Concentrate (kg/day)	16.98	14.98	18.73	15.53
Total feed (kg/day)	23.81	23.40	26.76	22.18
Total feed (kg/day)[a]	22.54	22.28	25.46	21.34
Actual milk (kg/day)	27.19	28.50	25.44	20.30
Milk fat (%)	2.81	2.77	2.76	3.26
F.C.M. (kg/day)	22.51	23.35	20.85	17.49
Conversion of F.C.M./kg of feed	1.00	1.05	0.82	0.82
Feed cost daily ($)	1.78	1.47	1.73	1.36
Feed cost/kg F.C.M.	0.079	0.063	0.083	0.078
Daily returns above feed costs ($)[b]	1.41	1.83	1.22	1.11

[a]Air dry basis (90% dry matter).

[b]Blend price $ .1415/kg 4% F.C.M.

hull and native grass hay rations was found to be, \$.0608/kg (\$2.76/45.4 kg or 100 lb), \$.0625/kg (\$2.84/45 kg), \$.0648/kg (\$2.94/45.4 kg), and \$.0614/kg (\$2.79/45.4 kg), respectively. The daily feed cost for the experimental rations were: control \$1.78, cottonseed hull \$1.73, alfalfa \$1.49, and \$1.36 for the native grass hay ration. The control ration had the highest daily feed cost, while the native grass hay ration had the lowest. The daily returns above feed cost were greatest for the alfalfa ration (\$1.83) and lowest for the native grass hay (\$1.11) with the control (\$1.41) and cottonseed hull (\$1.22) intermediate in returns. Similar results were reported by Leighton (38) when he found that the daily returns above feed cost were greater for complete feeds as compared to a conventionally-fed ration.

SUMMARY AND CONCLUSIONS

The objectives of this study were to compare the effect of ad libitum feeding of different roughage sources (30%) in a complete feed on the digestibility, rumen volatile fatty acids, fatty acids in the milk fat and the returns-above-feed cost using rumen-fistulated non-lactating and lactating animals. The roughages used in this study were: I - alfalfa hay (long and fed separately from concentrates), II - chopped alfalfa (approximately 2.5 cm lengths), III - cottonseed hulls, and IV - chopped native grass hay (approximately 2.5 cm lengths).

Chemical Analyses of Rations

Chemical analyses of rations were very similar to estimated chemical analyses, with the exception of the underestimation of the crude fiber content by Morrison's Tables.

Excretion Patterns of Chromium Ion

The excretion patterns of chromium ion by four rumen-fistulated animals fed the experimental rations were determined by feeding 10 g chromic oxide daily (0800) and collecting grab samples every two hr for 72 hours. The average relative per cent recovery rates of chromium ion when collection times of 0900 and 1900 were used were 94.4%, 102.2%, 98.9%, and 99.7% for the control, alfalfa, cottonseed hulls and native grass rations, respectively. An average relative per cent recovery rate of 98.8% for chromium ion was found for all rations.

Digestibility of Complete Rations Using Total Collection Method

No problem was encountered in the consumption of the complete rations by the rumen-fistulated animals. Similar daily feed intakes occurred for the control and alfalfa rations (16.67 kg), with the animals consuming the most of the cottonseed hulls ration (17.42 kg) and the least on the native grass hay ration (11.14 kg). On a gross energy basis the experimental rations were similar (4.06 - 4.25 Therms/kg), but considerable difference existed on a digestible energy intake (29.24 - 49.70 Therms daily). The calculated TDN over-estimated the actual TDN on all rations, with the greatest over-estimation occurring on the native grass hay ration.

Digestibility Using Indicator Method

The digestibility of the experimental rations fed to the sixteen lactating dairy animals was determined by the use of the chromic oxide indicator method. The average daily feed intake during the digestibility trial by the experimental animals on the control, alfalfa, cottonseed hulls, and native grass hay rations was 22.2 kg, 23.7 kg, 26.2 kg, and 23.5 kg, respectively. The digestible energy intakes were found to be 67.6 Therms for the control ration, 69.9 Therms for the alfalfa ration, 68.5 Therms for the cottonseed hulls ration and 59.2 Therms for the native grass hay ration. The digestible energy and TDN coefficients determined with the rumen-fistulated animals (total collection) over-estimated those determined with the lactating animals (indicator method), with the largest difference occurring in the estimation of TDN by the different methods. This would indicate that digestible energy provides a more accurate estimate of the nutritive value of a ration and some error will occur if digestibility coefficients obtained with non-lactating animals are applied to lactating animals.

TDN Requirements for Production

The TDN requirements for different levels of production were determined by dividing the daily kg of TDN consumed by the average daily kg of FCM produced on a period basis. The animals were then grouped according to different levels of production and their average requirement determined. Under the conditions of this study the lactating animals consumed in excess of their requirements for production and maintenance, providing Morrison's Tables are an accurate estimate of their requirements. When the lactating animals in this study were fed complete rations ad libitum, the most efficient producers were found to be those producing at the higher levels of production. The average TDN requirements for the control ration were the lowest, (0.38 kg/kg FCM), the control ration 0.41 kg/kg FCM, the native grass hay ration 0.44 kg/kg FCM, and the cottonseed hulls ration the highest, 0.51 kg/kg FCM.

Ration Effects on Rumen VFA

The effects of the experimental rations on the rumen volatile fatty acids and their level as a function of time were determined by use of the rumen-fistulated animals. Rumen fluid samples were collected at 0, 2, 4 and 6 hours after feeding for three consecutive days. The only significa: effect of the experimental rations as a function of time after feeding was on the acetate level ($P<0.01$). Acetate levels decreased 2 hours after feeding for all rations and continued to do so for the control and cottonseed hulls rations, while the acetate levels for the alfalfa ration and native grass hay ration increased. Significant effects between the levels of acetate ($P<0.01$), propionate ($P<0.05$) and butyrate ($P<0.01$) were found in the rumen-fistulated animals fed the experimental rations. Low levels of acetate and high levels of propionate were found in the rumen-fistulated non-lactating animals on the control and cottonseed hulls rations which would indicate that this might be a predisposing factor to low milk fat percentage. Lactating animals fed the control and cottonseed hulls rations produced milk with a lower milk fat percentage than the lactating animals on the alfalfa and native grass hay rations.

Ration Effects on Milk Fatty Acids

Analysis of variance of the levels of milk fatty acids indicated some significant effects had occurred due to rations and periods, but no uniform trends could be discerned. The differences that occurred between periods would suggest that further work needs to be done to establish the effect of stage of lactation and the position of attachment of the fatty acids to the glyceride radical.

Returns Above Feed Costs

The daily returns above feed cost were found to be greatest for the alfalfa complete feed (\$1.83) and smallest for the native grass hay ration (\$1.11), with the control (\$1.41) and cottonseed hulls ration (\$1.22) intermediate in returns. Daily feed cost were highest for the control (\$1.78) and cottonseed hulls ration (\$1.73), and lowest for the alfalfa (\$1.46) and native grass hay rations (\$1.36).

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APPENDIX

TABLE 1a

Chemical Analyses of Ingredients Used in Experimental Rations

Ingredients[a]	Crude Protein	Crude Fiber	Ether Extract	NFE	Ash	Moisture	DM
	- - - - - - - -	- - - - - - - -	- - - - - - - -	Per Cent	- - - - - - - -	- - - - - - - -	- - - - - - - -
Alfalfa hay	13.30	28.30	3.10	34.40	7.70	13.20	86.8
Cottonseed hulls	3.40	38.70	0.90	42.20	2.40	12.40	87.6
Native grass hay	7.00	31.90	2.00	42.90	7.00	9.20	90.8
Concentrate (control)	16.11	7.78	2.25	57.59	5.82	15.40	84.6
Corn	8.90	1.90	3.90	70.40	1.10	13.80	86.2
Soybean oil meal	44.60	10.00	2.60	27.20	6.30	9.30	90.7
Cottonseed meal	39.40	7.40	6.70	33.20	7.20	6.10	93.9
Molasses	3.50	--	--	70.30	6.20	20.00	80.0

[a]Average of 10 chemical analyses.

TABLE 2a

Relative Per Cent Recovery of Chromium Ion from Rumen-Fistulated Animals Fed Experimental Rations

Time	Rations I Control	II Alfalfa	III CSH	IV Native Grass
	Per Cent			
0100	78.1	77.0	75.8	103.4
0300	81.4	82.9	92.6	118.2
0500	84.6	94.8	101.0	96.0
0700	93.1	103.5	126.3	92.3
0900	104.2	112.6	113.6	99.7
1100	113.9	118.5	122.1	81.2
1300	117.2	118.5	109.4	103.4
1500	127.0	109.6	101.0	110.8
1700	110.7	103.7	117.8	114.5
1900	84.6	91.8	84.2	99.7
2100	97.7	94.8	75.8	96.0
2300	107.4	91.8	80.0	84.9
0900 and 1900 Av	94.4	102.2	98.9	99.7

TABLE 3a

Summary of VFA Found in the Rumen-Fistulated Animals at Various Time Intervals

Ration	Hr	Carbon Number			
		C_2	C_3	C_4	C-2/C-3
		Per Cent			
I	0	47.5[a]	37.2	15.3	1.3
	2	45.3	38.8	16.0	1.2
	4	45.3	38.9	15.8	1.2
	6	43.4	38.6	18.0	1.1
	Average	45.4	38.4	16.3	1.2
II	0	55.0	25.3	19.7	2.2
	2	53.9	26.0	20.0	2.1
	4	54.4	25.9	19.7	2.1
	6	55.6	25.0	19.4	2.2
	Average	54.7	25.6	19.7	2.2
III	0	50.0	30.1	19.9	1.6
	2	47.5	31.5	21.0	1.5
	4	44.7	31.1	24.2	1.4
	6	41.2	34.3	24.5	1.2
	Average	45.9	31.8	22.4	1.4
IV	0	56.4	23.4	20.2	2.4
	2	54.9	24.5	20.6	2.7
	4	55.1	23.4	21.5	2.4
	6	56.9	23.1	20.1	2.5
	Average	55.8	23.6	20.6	2.5

[a]Average 3 chemical analyses.

TABLE 4a

Mean Squares of Analyses of Variance for VFA Collected from Rumen-Fistulated Animals Fed Experimental Rations

Variance Source	d.f.	C-2	C-3	C-4
Rations	3	377.55**	535.88**	78.82**
Error A	8	3.13	7.56	5.80
Time	3	19.57**	3.98	7.64
Time x ration	9	14.09**	3.21	4.60
Error B	24	3.51	4.74	4.50

*Significant at $P<0.05$.
**Significant at $P<0.01$.

TABLE 5a

Cost of Ingredients Used in Experimental Rations

Ingredient	kg	45.4kg(100 lb)
	- - - - - - - - - - ($)	- - - - - - -
Shelled corn (#2)	.0649	2.95
Urea (42%)	.1084	4.93
Soybean oil meal (SBOM)	.1155	5.25
Cottonseed meal (44%, CSM)	.1056	4.80
Molasses	.0226	1.03
Steamed bonemeal	.1265	5.75
Salt	.0284	1.29
Alfalfa hay	.0468	2.13
Cottonseed hulls (CSH)	.0462	2.10
Native grass hay (NGH)	.0275	1.25
Chopping costs	.0062	0.28
Control ration (I)	.0608	2.76
Alfalfa complete ration (II)	.0625	2.84
CSH complete ration (III)	.0648	2.94
NGH complete ration (IV)	.0614	2.79

AUTOBIOGRAPHY

Rustum Ernest Girouard, Jr. was born March 21, 1940, at Kaplan, Louisiana. He was the first of seven children born to Rustum Ernest Girouard and Frances Broussard.

He graduated from Kaplan High School in the Spring of 1958 and immediately entered Louisiana State University at Baton Rouge.

On March 3, 1962, he was married to the former Miss Alice F. Simon.

In August, 1962, he received a Bachelor of Science degree in Agriculture and entered the Graduate School at Louisiana State University in September, 1962. He received a Master of Science degree in the field of Animal Nutrition in August, 1964.

From February, 1964 to September, 1965, he was employed as an instructor in the Department of Dairy Science. He resigned from the above job in September, 1965, to continue his studies toward a Doctorate degree with a major in the field of Animal Nutrition and a minor in the field of Poultry Nutrition. He completed the requirements for the degree in January, 1968.

EXAMINATION AND THESIS REPORT

Candidate: Rustum Ernest Girouard, Jr.

Major Field: Dairy Nutrition

Title of Thesis: Complete Rations for Dairy Cattle and Their Effects Upon Digestibility, Rumen Volatile Fatty Acids and Milk Fatty Acids.

Approved:

Louis L. Rusoff
Major Professor and Chairman

Max Goodrich
Dean of the Graduate School

EXAMINING COMMITTEE:

A. B. Watts

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J. D. Roussel

Date of Examination:

September 18, 1967